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RESEARCH PAPER

Reduction of incidence of weeds in maize through the use of cover species

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Abstract

This study aimed to evaluate the effectiveness of different cover crops in suppressing weed emergence and their influence on maize productivity under field conditions in Concepción, Paraguay (23°25'40.3"S, 57°20'00.2"W) from October 2021 to June 2022. A completely randomized design was employed with four treatments and seven replications. The treatments consisted of using cover crop species, which were planted in the research area subsequently used to cultivate maize. The cover crops used were *Urochloa ruziziensis* cv. ruziziensis, *Stizolobium pruriens*, a mixture (*Urochloa ruziziensis* cv. ruziziensis + *Stizolobium pruriens*) and a conventional system. The experiment consisted of two stages: first, the installation of the cover crop species, followed by the planting of the maize. Ninety days after planting the cover crop species, the cover crop plants were cut down. Thirty days later, Triple pro DKB360 hybrid maize was sown. The parameters evaluated in the first stage were green weed mass, dry weed mass, green crop mass, and dry crop mass at 90 days after sowing (DAS). In the second stage, the parameters evaluated were green mass of weeds at 20, 35, 50 and 65 DAS; weed suppression at 20, 35, 50 and 65 DAS; cover persistence at 0, 20, 35, 50 and 65 DAS; plant height at 35 and 110 DAS; number of grain rows per ear; number of grains per row; and yield. Variance analysis was carried out on the data using the F-test at 5%, and Tukey's test at 5% was used to compare the means of the treatments. The mixture of *U. ruziziensis* and *S. pruriens* significantly reduced weed biomass by 43.2% compared to the conventional system and showed the highest weed suppression and cover persistence up to 65 days after sowing. Moreover, this mixture produced the highest maize yield (8.42 Mg ha^{-1}), representing a 39.4% increase over the conventional system. Treatments with *U. ruziziensis* alone also outperformed the control, while *S. pruriens* alone had limited effectiveness. These results highlight the potential of using mixed cover species as a sustainable weed management strategy that enhances maize productivity in smallholder systems.

Keywords

Cover crop mixture, *Stizolobium pruriens*, *Urochloa ruziziensis* cv. ruziziensis, weeds, *Zea mays*

Introduction

One of the requirements for employing a crop rotation system is to use cover crops. Cover crops contribute to preventing damage from raindrops, enhance weed control, and increase organic matter, which in turn improves the physical and chemical properties of the soil (Servín et al. 2022).

Cover crop species are plants grown to generate a layer of soil cover that serves as a base for no-till farming. The different species used have one or more known

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characteristics that, when properly combined and managed, offer advantages such as nitrogen fixing, recycling of nutrients, repelling pests, and also a decrease in the incidence of weeds, which allows for a reduction in herbicide application (Martínez et al. 2017).

Green manure species are used during the phenological cycle before proceeding to plant the economically important crop. This is done to mitigate any damage that may be caused to the soil and, most importantly, to maximise the productivity of the crops of interest. However, the results of the transition from conventional practices to no-till sowing (crop rotation) are not immediate, and time is needed to reach established objectives (Sanabria-Quispe et al. 2023).

The phytomass produced by plant cover species has a direct impact on the elimination of weeds in agroecosystems: there is a linear correlation between the quantity of this phytomass and the effective reduction of incidence of weeds. Different cover crop species modify the composition of weed populations (Severino et al. 2001).

In family farming in Paraguay, summer green manures are widely used before sowing maize as an income crop and for consumption by humans and small livestock, the establishment of cover crops occurs between September and December, with maize planting taking place between September and March. In Paraguay, maize accounts for a significant proportion of income crops, contributing significantly to the generation of foreign currency in the country. Nationally, there was an average crop yield of 4.148 kg·ha^{-1} in the 2021 agricultural season and 5.016 kg·ha^{-1} in the 2022 agricultural season (CAPECO 2022).

Maize has high yield potential but is very sensitive to stress: this explains the plant's notable response to correct agronomic management. Its growth is directly related to its ability to capture sunlight for photosynthesis, which depends on the structure of the crop and type of plant, the quantity of plants, and their distribution (Cirilo et al. 2006; da Silva et al. 2022; Fernández et al. 2022).

For this reason, it is necessary to introduce plants capable of covering the greatest possible percentage of the soil, so that it remains covered for as long as possible to reduce the incidence of weeds. The use of plant cover in the crop rotation or intercropping systems of family farmers looks to promote soil recovery by improving the physical, chemical and biological properties of the soil. These benefits are achieved because soil tillage, which could cause deleterious effects to the soil, is not carried out (Servín et al. 2018).

In light of the above, the main objective of this experiment was to evaluate the use of different cover crops and their impact on weed emergence, considering maize productivity parameters.

Material and methods

This study was carried out from October 2021 to June 2022 in the experimental plot of the Agricultural School of Concepción, (Concepción – Paraguay) at geographical coordinates latitude 23°25'40.3"S, 57°20'00.2"W longitude at altitude 242 masl in Concepción - Paraguay. The soil was classified as being of order Alfisol and subgroup Mollic Paleudalf (López et al. 1995). Soil samples were extracted prior to the initiation of the cover crop experiment. Soil samples were airdried, ground, passed through a 2 mm sieve, and analysed for soil pH in a 1 :1 water suspension (Tedesco et al. 1995). Soil organic carbon (SOC) was determined by the Walkley–Black method (Tedesco et al. 1995). P, K, Ca, and Mg were analysed using Mehlich^{-1} extractant (Tedesco et al. 1995). Potential acidity (H + Al) was measured using the SMP bu/er method (Shoemaker et al. 1961). Cation exchange capacity (CEC) at pH 7.0 was calculated by adding the exchangeable basic cations Ca^{+2}, Mg^{+2}, and K^{+} and the potential acidity (H + Al) (van Raij, 2011). Base saturation (V%) was calculated by dividing the values of the basic cations by the CEC and then multiplying by 100 (van Raij, 2011). Selected chemical characteristics of the soil at a depth of 0–20 cm were P (Mehlich^{-1}): 10.43 mg·dm^{-3}; O.C.: 0.520 g·dm^{-3}; pH ($CaCl_2$): 5.98; K: 0.05 cmol·dm^{-3}; Ca + Mg: 2.50 cmol·dm^{-3}; H+ Al: 0.05 cmol·dm^{-3}; SB: 3.41 cmol·dm^{-3}; CIC: 5.56 cmol·dm^{-3}; and V%: 42.56. The data for mean temperature and accumulated precipitation during the experiment are shown in (Fig. 1) (DMH 2022).

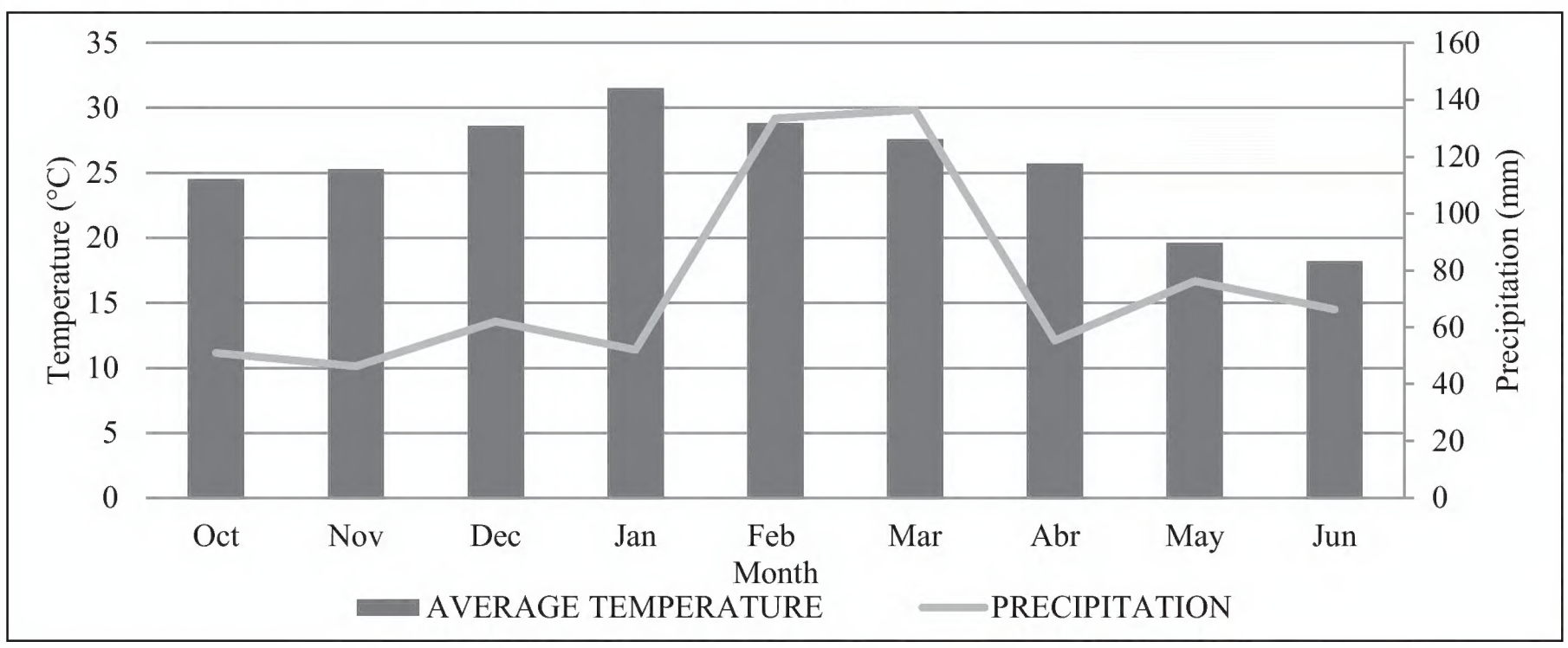

Figure 1. Data for mean temperature and accumulated precipitation from October 2021 to June 2022.

The experimental design used was a completely randomized design (CRD) consisting of 4 treatments and 7 replications, using 28 experimental units (EU). The experiment consisted of two stages: first, the establishment of the cover crop species, and subsequently the planting of maize over the cover crop. The treatments consisted of using cover crops in the research area in which the maize was to be planted. The cover crops used were *Urochloa ruziziensis* cv. ruziziensis (T1), *Stizolobium pruriens* (T2), a mixture (*Urochloa ruziziensis* cv. ruziziensis + *Stizolobium pruriens*) (T3) and a conventional system (T4). Each experimental unit had dimensions of 6 m by 5 m (30 m^2), with 0.5 m between rows and 0.3 m between plants. The effective plot size was 5 m^2.

The plot was selected for the experiment weeks before planting, taking into account the uniformity of the soil, incline, and accessibility. Preliminary field preparation consisted of the plot was manually hoed, and the uniformity of the terrain was analysed. Once the plot had been cleared, measurements were taken to delineate the area by placing a stake in each corner and using a square for precision. The dimensions were 42 m by 20 m, giving a total experimental area of 840 m^2. The species used for the study were *Urochloa ruziziensis* cv. ruziziensis (T1), *Stizolobium pruriens* (T2), a mixture (*Urochloa ruziziensis* cv. ruziziensis + *Stizolobium pruriens*) (T3) and a conventional system (T4), which was used as a control. In the first week of September, *Stizolobium pruriens* was sown manually with spacing of 0.45 m x 0.45 m at a depth of approximately 2 cm (de Jesús et al. 2007). Spacing of 0.45 m between rows was used for *Urochloa ruziziensis* cv. ruziziensis, employing a row seeding technique with 40 seeds per linear metre. For the mixture treatment, the cover species were arranged alternately along the rows, following the experimental design, Stizolobium pruriens and *Urochloa ruziziensis* cv. ruziziensis were planted in alternating rows. For the conventional system, soil tillage was carried out manually using hoes at a depth of 0–20 cm (Moura et al. 2008; Haring et al. 2022) 15 days before planting the maize. Weeding was only carried out in the walkways during the experiment; it was done manually, using traditional tools. The purpose of this weeding was to clearly individualise the experimental units, thus facilitating access for monitoring, measuring, and avoiding the application of herbicides that might affect the cover crops. At 90 DAS, the cover plants were cut down (Simidu et al. 2010) using a Husqvarna two-bladed weed cutter. Thirty days after the cutting down of the cover crops (Servín et al. 2022), Triple pro DKB360 hybrid maize was sown with a density of 0.50 m between rows and 0.30 m between plants at a depth of 2 cm (Nunes et al. 2022). Each hole contained two seeds. Planting was done manually using a seed drill. In order to obtain a grain yield of 5 Mg ha^{-1}, a mineral fertilization program was implemented. Urea (containing 46% nitrogen), triple superphosphate (with 46% phosphorus pentoxide), and potassium chloride (60% potassium oxide) were selected as the nutrient sources. Fertilizer rates were calculated based on the crop's nutrient export per tonne of grain produced, along with maintenance requirements and anticipated losses of 25%. The final application rates were established at 393 kg ha^{-1} of urea, 380 kg ha^{-1}TSP, and 229 kg ha^{-1} KCl. Fertilisation was carried out with nitrogen (145 kg ha^{-1}); phosphorus (140 kg ha^{-1}) and potassium (110 kg ha^{-1}). Nitrogen application was carried out twice: on sowing the maize (30%) and when the plants had eight true leaves (70%) (Almeida et al. 2020). Phosphorus and potassium were applied once (20 DAS) by hand at locally recommended rates (D'Amours et al. 2023). No weeding was carried out as weeds were very scarce due to the dead vegetable cover minimising weed development. Thinning of the maize plants was carried out because two seeds were placed in each hole when sowing. Phytosanitary treatments were carried out at an interval of 15 days in order to prevent insect and fungal attacks. The insecticide used was Phenylpyrazole 80 at a dosage of 10 g/20 l tank. The fungicide used was Benzimidazole at a rate of 1 l ha^{-1}.

The following variables were measured in relation to the plant cover species. Green mass (Mg ha^{-1}): green mass was measured 90 days into the crop cycle. A 1 m^2 polyvinyl chloride (PVC) square was used; it was thrown randomly into the replications of each treatment, and the plants inside the square were harvested and weighed using a scale with precision of 0.005 g (Simidu et al. 2010). Crop dry mass (Mg ha^{-1}): to measure dry mass, the samples that had been evaluated for green mass were placed in a forced circulation oven at 65 °C for 72 hours (Cabral et al. 2013; Martins et al. 2013). Green mass of weeds (Mg ha^{-1}): the green biomass of weeds present in the treatments was measured manually at ground level (Zaidan et al. 2022) using a 1 m^2 PVC square. The square was randomly thrown into the replications of each treatment. For the evaluation of this variable at 90 DAS, another section of the EU was chosen at random. The weeds located within the square were collected and weighed using a scale with precision of 0.005 g (Maszura et al. 2018). Weed dry mass (Mg ha^{-1}): to measure the dry mass of weeds, the samples evaluated for weed green mass were placed in a forced circulation oven at 65 °C for 72 hours. In the second stage of the experiment, the green mass of weeds (Mg Ha^{-1}) was evaluated. A 1 m^2 PVC square was randomly thrown in each experimental unit. Weighing was carried out at 20, 35, 50 and 65 days after sowing the maize (DASM). The weeds located within the square were collected and weighed on a scale with precision of 0.005 g. Weed suppression (Mg ha^{-1}): the control treatment (T4: conventional system) was used as a reference (Buchling et al. 2020) for determining green mass of weeds and weed suppression. Formula (01) was used to obtain values for weed reduction at 20, 35, 50 and 65 DASM, following the methodology of Silva et al. (2009):

$$WS = CT - TGM \quad (01)$$

where WS is weed suppression Mg·ha^{-1}, CT is the control treatment, and TGM is treatment with green manure crops. Persistence of cover (Mg Ha^{-1}): cover crop mass from a single 1 m^2 area was weighed at 0, 20, 35, 50 and 65 days after planting maize using scales with precision of 0.0005 g.

The following variables were measured in relation to the maize plants. Plant height (cm): a tape measure was used to measure plant height from the plant base to the collar of the upper leaf of 30 plants selected from the useful plot of each EU at 35 and 110 DASM (Steusloff et al. 2019). Number of grain rows per ear: 40 ears were selected from each experimental unit and the rows of each of the ears were counted and averaged. Number of grains per row: the average grains per row of 40 ears from each treatment was calculated using plants selected at random from the useful plot (Lorenzetti et al. 2021). Yield (Mg ha^{-1}): the harvesting process began at 150 DAS. Two harvesting operations were carried out, with ears collected manually (Panison et al. 2016). The total useful area was harvested, and the weight of the grain was measured on precision scales when the grains reached 13% moisture (Trogello et al. 2013; Janak et al. 2016). Data Analysis. The data obtained from each treatment were statistically evaluated. Variance analysis (5% F-test) was used to verify whether there were significant differences between treatments. Means were subsequently analysed using Tukey's test at 95% significance level (Wagner et. al. 2013). A free statistical software called AgroEstat (Barbosa and Maldonado 2015) was used.

Results

Shows the means of the green mass of weeds with the use of cover crop species. Treatment T3 was statistically superior to the other treatments, followed by treatment T1 (Tukey test 5%) (Table 1).

Regarding the dry mass of weeds, treatment T3 and T1 were statistically superior, followed by treatments T1, T2 and T4, which were similar. The means of green crop mass for treatments T1, T2 and T3 are shown; treatments T3 and T1 were statistically similar, while T2 was inferior to the other treatments. In relation to dry crop mass, it can be seen that treatments T3 and T1 were statistically equal and superior to treatment T2.

The data on green mass of weeds in Table 2 (Mg Ha^{-1}) show that significant differences were seen between the readings taken at the different time intervals (20, 35, 50 and 65 DAS). At 20 DASM, the best performance was seen from the mixture of *Urochloa ruziziensis cv. ruziziensis* and *Stizolobium pruriens* (U+S), followed by *Urochloa ruziziensis* cv. *ruziziensis*, *Stizolobium pruriens*, while the conventional system had the highest amount of GMW per hectare.

Table 3 shows a comparison of the means for the variable of weed suppression, using the conventional system as the main parameter. Significant differences were observed in all measurements, with higher

weed suppression values shown by the mixture of *Urochloa ruziziensis cv. ruziziensis* and *Stizolobium pruriens* (U+S). It can also be seen that *Urochloa ruziziensis cv. ruziziensis* (T1) presented greater weed suppression than *Stizolobium pruriens* (T2)

Table 4 shows that significant differences were found for cover persistence between 0, 20, 35, 50 and 65 DASM using Tukey's test at 5%. The treatment with the mixture of cover crops showed the highest and most effective result (U+S).

Table 5 shows that plant covers had a positive effect on maize plant height at both 35 DAS and 110 DAS. There were significant differences between the conventional system and the use of plant cover. The comparison of means using Tukey's test (5%) for the number of grains per row and number of grain rows per ear is also displayed; there was a significant effect on the number of grains per row and number of rows.

For the variable of yield, the mixture of *Urochloa ruziziensis cv. ruziziensis* and *Stizolobium pruriens* produced the best results, followed by the cover with just *Urochloa ruziziensis cv. ruziziensis*, then by *Stizolobium pruriens* and the conventional system; these last two were statistically equal.

Discussion

Green mass of weeds (GMW) and dry mass of weeds (DMW)

Through the use of plant species for vegetation cover, it was possible to reduce the appearance of harmful plants by 43.2%, 25.8% and 9.8% respectively for the mixture (U+S), *Urochloa ruziziensis cv. ruziziensis* and *Stizolobium pruriens*. This is because competition for light, water, nutrients, etc. is much lower.

These results coincide with those of Perez and Scianca (2010), who mention that the use of oats as a cover crop led to a lower number of weeds than in the control. The results also coincide with the findings of Sardiña et al. (2008), who found that the use of cover crops reduces the number of weeds per square metre.

Table 1. Comparison of means of green mass of weeds (GMW), dry mass of weeds (DMW), green mass of crop (GMC) and dry mass of crop (DMC) (Mg ha^{-1}) at 90 DAS of the cover plants.

Treatments	GMW (Mg ha^{-1})	DMW (Mg ha^{-1})	GMC (Mg Ha^{-1})	DMC (Mg Ha^{-1})
(T1) *Urochloa ruziziensis*	7.42 b	2.51 ab	9.37 a	3.77 a
(T2) *Stizolobium pruriens*	9.02 c	2.68 b	6.65 b	2.48 b
(T3) Mixture (U+S)	5.68 a	2.20 a	10.00 a	3.80 a
(T4) Conventional system	10.00 c	2.97 b		
OM:	8.03	2.59	8.88	3.35
VC (%):	13.39	12.42	14.38	18.89
MSD (5%):	1.58	0.47	1.74	0.86

*Different letters are statistically different when the Tukey test at 5% is applied. OM. Overall mean; VC(%): Variation coefficient; MSD (%): Minimum significant difference.

Table 2. Comparison of means of green mass of weeds (GMW) (Mg Ha^{-1}) using vegetative cover in maize cultivation.

Treatments	GMW (Mg Ha^{-1})			
	20 DAS	35 DAS	50 DAS	65 DAS
(T3) Mixture (U+S)	2.28 a	4.33 a	9.35 a	14.20 a
(T1) *Urochloa ruziziensis*	3.44 b	6.26 b	12.13 a	15.58 ab
(T2) *Stizolobium pruriens*	4.08 b	6.52 b	13.08 a	16.42 b
(T4) Sistema convencional	5.92 c	8.09 c	14.03 b	18.23 c
VC(%)	18.79	9.08	11.28	6.90
MSD	1.09	0.84	2.02	1.63
OM	3.93	6.30	12.15	16.11

*Different letters are statistically different when the Tukey test at 5% is applied. OM: Overall mean; VC(%): Variation coefficient; MSD (%): Minimum significant difference; DAS: Days after sowing.

Table 3. Comparison of means of weed suppression (WS) (Mg Ha^{-1}) using vegetative cover in maize cultivation.

Treatments	WS (Mg Ha^{-1})			
	20 DAS	35 DDS	20 DAS	65 DDS
(T3) Mixture (U+S)	3.63 a	3.76 a	4.68 a	4.03 a
(T1) *Urochloa ruziziensis*	2.58 ab	1.83 b	1.89 b	2.65 ab
(T2) *Stizolobium pruriens*	1.83 b	1.57 b	0.94 b	1.80 b
VC(%)	16.85	14.37	15.49	12.37
MSD	1.34	0.79	2.58	1.63
OM	2.68	2.39	2.50	2.83

*Different letters are statistically different when the Tukey test at 5% is applied. OM: Overall mean; VC (%): Variation coefficient; MSD: Minimum significant difference; DAS: Days after sowing.

Table 4. Comparison of means of cover persistence (CP) (Mg Ha^{-1}) using vegetative cover in maize cultivation.

Treatments	CP (Mg Ha^{-1})				
	0 DAS	20 DAS	35 DAS	50 DAS	65 DAS
(T3) Mixture (U+S)	9.14 a	7.36 a	5.21 a	3.97 a	2.88 a
(T1) *Urochloa ruziziensis*	7.71 b	6.26 b	4.78 a	3.12 b	2.07 b
(T2) *Stizolobium pruriens*	6.12 c	4.79 c	3.28 b	1.93 c	0.89 b
VC(%)	9.19	8.69	16.22	17.24	13.69
MSD	0.96	0.72	1.02	0.70	0.74
OM	7.66	6.14	4.43	3.01	1.95

Averages followed by the same letter do not differ when analysed using Tukey's Test at 5%. OM: Overall mean; VC (%): Variation coefficient; MSD: Minimum significant difference. DAS: Days after sowing.

Kahl et al. (2016) found that the use of cover crops reduces the appearance of weeds compared to the conventional system. These results were similar to those of the present study.

Through the results obtained, we can affirm that the incidence of harmful plants in the crop was reduced, allowing for maximisation of the productivity of the economically important crop.

The most efficient reduction in the incidence of weeds was achieved using the mixture of cover crops (U+S), followed by *Urochloa ruziziensis* cv. ruziziensis, and then *Stizolobium pruriens*, which was the most inefficient of the cover crops used.

When evaluating the correlation between use of different amounts of vegetative cover phytomass and the reduction of incidence and dry phytomass of weeds, Severino and Christoffoleti (2001) found that it was possible to reduce the density and dry biomass of weeds. This study's results coincide with their findings.

Green mass of crop (GMC) and dry mass of crop (DMC)

Through use of the mixture of cover crops, it was possible to increase vegetative cover by 50.37% compared to the *Stizolobium pruriens* monoculture. This could be mainly due to the fact that the Poaceae family species used presented higher growth than the Fabaceae species used. This is because the Poaceae has C4 metabolism while the Fabaceae has C3. As such, *Urochloa ruziziensis* cv. ruziziensis reduces energy expenditure to a minimum by concentrating on the production of green mass.

An experiment conducted by Ruiz and Cerritos (2021) to evaluate the growth and development of three species of cover crops, alongside their efficiency in reducing the appearance of weeds, showed a significant difference. The soil cover and biomass provided by the cover crops favoured weed suppression, coinciding with the results of the present study.

An increase of 52.01% in the production of cover crop dry mass was recorded when using the mixture of cover crops in comparison to the *Stizolobium pruriens* monoculture; this could be due to a higher rate of growth. In an experiment conducted by Scianca et al. (2007) to evaluate the efficiency of dry mass production by three species of cover crops and their impact on weed dynamics, it was found that, as the different cover crops developed, weed density decreased. These results coincide with those of the present study.

Table 5. Comparison of means for maize plant height (MH), number of grains per row (N° GR) and number of rows per ear (N° RE), yield (Y) using cover crops.

Treatment	MH (m)		N° GR	N° RE	Y (Mg ha^{-1})
	35 DAS	110 DAS			
(T3) Mixture (U+S)	0.59 a	1.42 a	31.02 a	15.94 a	8.42 a
(T1) *Urochloa ruziziensis*	0.57 b	1.46 a	28.42 b	15.44 a	6.04 b
(T2) *Stizolobium pruriens*	0.47 b	1.41 a	28.25 b	14.56 b	4.27 c
(T4) Conventional system	0.37 c	1.34 b	27.12 c	14.08 b	3.79 c
VC(%)	0.83	0.06	3.04	3.61	10.86
MSD	0.50	1.41	1.29	0.79	0.90
OM	11.25	3.23	28.76	15.00	5.63

Means followed by the same letter do not differ when analysed using Tukey's Test at 5%. OM: Overall mean; VC (%): Variation coefficient; MSD: Minimum significant difference. DAS: Days after sowing.

Green mass of weeds (GMW) (Mg Ha^{-1}), weed suppression (WS) (Mg Ha^{-1}) and cover persistence (CP) (Mg Ha^{-1})

At 35 DASM there was a reduction in weed incidence of 46.47, 22.62 and 19.40% respectively for the mixture (U+S), *Urochloa ruziziensis* cv. ruziziensis and *Stizolobium pruriens*. The same behaviour was observed at 50 and 65 DASM compared to the conventional system.

According to Servín et al. (2022), the use of vegetative cover radically reduces weed development because weeds do not have access to light. As such, the incidence of weeds in the economically important crop is reduced, providing great benefit. Similar results were observed in this experiment. Coelho et al. (2016) state that the reduction in green mass of weeds is a result of the high C/N ratio, the volume of plant residue, and its uniform coverage on the soil. This was also observed in the current experiment. Spíndola et al. (2020) carried out a study on the impact of plant cover on weed management and common bean yield. They found that the use of *Urochloa ruziziensis* cv. ruziziensis reduced the amount of weeds per hectare compared to other Fabaceae species used, such as *Crotalaria* sp. The same behaviour was also observed in this study. Similarly, Fernandez et al. (2022) evaluated the decrease in weed occurrence in maize crops. They found that the use of *Urochloa ruziziensis* cv. ruziziensis decreased the green mass of weeds compared to the conventional system; similar results were recorded in this study.

Undoubtedly, the use of *Urochloa ruziziensis* cv. ruziziensis and *Stizolobium pruriens* in monoculture produced a significant increase in weed suppression. However, the mixture of both species produced an increase in weed suppression of 28.9% and 50.41% compared to *Urochloa ruziziensis* cv. ruziziensis and *Stizolobium pruriens* alone respectively at 20 DASM. This could be mainly due to the cover crops' persistence on the soil surface. At 35, 50 and 65 DASM, weed suppression was 51.3, 59.6 and 34.2% higher for the mixture (U+S) than for *Urochloa ruziziensis* cv. ruziziensis alone. In the same fashion, the mixture (U+S) produced weed suppression 58.2, 79.9 and 55.33% higher when compared to the *Stizolobium pruriens* alone.

According to Marasca et al. (2021), plant residue on the soil surface, specifically cover by poaceae and fabaceae, decreased weeds when compared to the conventional system. This behaviour was also observed in the present study. The greater persistence of cover is a product of the high C/N ratio, which leads to slow degradation in the soil; the volume of plant residue and its uniform coverage on the soil considerably contribute to decreasing the incidence of weeds. It was also seen in this study that that, at the time of planting the maize (0 days), all treatments displayed between 9.14 and 6.12 Mg Ha^{-1} of phytomass. These levels are considered ideal, as the production of 5 Mg Ha^{-1} is required to cover the entire soil and maintain subsequent cover, according to Silva et al. (2009). Reduction in soil cover from 0 days to 65 days was of 68.4, 73.15 and 85.45% respectively for the mixture (U+S), *Urochloa ruziziensis* cv. ruziziensis and *Stizolobium pruriens*. Padovan et al. (2013) recorded means beginning at 6.85 Mg Ha^{-1}, which is within the parameters observed in this study. The main weed species found before and during the experimental measurement period were *Digitaria insularis* L., *Digitaria bicornis* (Lam.) Roem. & Schult., *Commelina erecta* L., *Cenchrus echinatus* L., *Conyza bonariensis* (L.) Cronquist var. *bonariensis*, *Gamochaeta calviceps* (Fernald) Cabrera, *Amaranthus blitum* L., *Sida rhombifolia* L., *Tridax procumbens* L., *Cleome aculeata* L., *Ipomoea grandifolia* (Dammer) O´Donnell, *Boerhavia diffusa* L., and *Cucurbitella asperata* ((Gillies ex Hook. and Arn.) Walp.).

Maize plant height (MH) (m), Number of rows, number of kernels per row, and maize yield

Regarding the variable of maize plant height (m), an increase was observed in the treatments with vegetative cover when compared to the conventional system. This could be a consequence of the greater amount of green mass of weeds in T4, leading to direct competition for light, nutrients and water, and resulting in a lower height of the maize plants. This behaviour was not observed where vegetative cover was used. Rieppi (2019) evaluated the impact of reduced tillage and the use of green manures on the vegetative and productive properties of maize; it was found that the use of vegetative cover led to greater plant height compared to the conventional system. Similar results were found in this study. Likewise, Muñoz (2019), when comparing maize cultivation in monoculture and conservation agriculture, found that the monoculture system produced plants that were smaller than when vegetative cover was used. Similar results were observed in the present study using different vegetative covers. Cambaúva et al. (2019) studied the growth and productivity of maize in a conventional system and in a rotation system. They found that the maize plants in the conventional system reached greater height compared to those where vegetative cover was used; these results differ from those found in the present experiment.

In relation to the variable of number of rows per ear, an increase was observed when using the mixture (U+S), which displayed significant difference. An increase in the number of rows of 13.2% was achieved with *Urochloa ruziziensis* cv. Ruziziensis + *Stizolobium pruriens* in comparison to the conventional system. As the Fabaceae used rapidly decomposed, it was replaced by spontaneous vegetation (weeds) as in the conventional system; these did not provide any cover, and the result was a lower number of rows per ear. Servín et al. (2023) evaluated the effect of summer green manure species cover on maize traits. They found that the use of vegetation cover produced significant differences in relation to the number of grains per row and number of rows per ear; analogous results were recorded in the present study. Similarly, Albuquerque et al. (2013) used cover crops and nitrogen fertilisation in maize production in a no-tillage system.

They observed that this system allowed for a maximisation of the number of rows per ear; similar results were found in the present study. It was found that the mixture (U+S), *Urochloa ruziziensis* cv. Ruziziensis and *Stizolobium pruriens* led to an increase of 122.16, 59.36 and 12.66% respectively compared to the conventional system. This indicates an important increase in maize productivity when using cover crops as a weed suppressor. Fernandez et al. (2022) studied the decrease in the occurrence of weeds in maize crops. They found that the use of *Urochloa ruziziensis* cv. Ruziziensis as a cover crop considerably increased maize yield. Similar results were observed in this experiment. Furthermore, Servín et al. (2023) evaluated the effect of summer green manure species cover on maize traits. They found that the use of cover crops increased maize yield compared to the conventional system; similar behaviour was observed in the present experiment. In line with the results of the current experiment, Ricklivan Westering et al. (2020) found that the use of vegetative cover maximised maize productivity compared to the conventional system.

Beyond weed control, cover crops significantly influence soil fertility through their effects on organic matter dynamics and nutrient cycling. Grasses such as U. ruziziensis typically have a higher carbon-to-nitrogen (C/N) ratio, which slows down residue decomposition, ensuring longer-lasting soil cover and gradual nutrient release. In contrast, leguminous species like S. pruriens have a lower C/N ratio, decomposing more rapidly and contributing readily available nitrogen to subsequent crops. When used in combination, these species promote a balanced decomposition process, improving synchrony between nutrient release and crop demand, while maintaining physical protection of the soil surface (Appelgate et al. 2017). Therefore, the functional complementarity between species with contrasting C/N ratios enhances both weed suppression and soil nutrient availability, reinforcing the agronomic value of mixed cover crop systems.

Conclusion

The combined use of *Urochloa ruziziensis* and *Stizolobium pruriens* demonstrated strong potential as a sustainable and efficient strategy for weed suppression in maize cultivation. This mixture not only reduced weed incidence by 43.2% compared to the conventional system but also significantly enhanced cover persistence and maize yield, with a productivity increase of 39.4%. The results underscore the advantages of integrating mixed cover crops into cropping systems, particularly for smallholder farmers seeking to reduce herbicide use and improve soil health. By maintaining soil coverage and suppressing weed emergence during critical crop growth stages, these cover species contribute to more resilient and productive agroecosystems.

Conflict of interest statement

The authors declare that there are no conflicts of interests in relation to the publication of this article.

Author's contributions

FCO designed the experiments; RGE, AFS, DLA and FFA carried out the field and laboratory experiments; MODO, HGV and AISN contributed to the data analysis, AISN and AMHM wrote the article. All authors reviewed the final version of the manuscript.

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